COMPARATIVE NEUROLOGY.

BY S. V. CLEVENGER, M.D.

WHAT can we say of the nervous system of Protozoa, but that it exists in a diffuse undifferentiated state? If we speak of a nerve force it implies the existence of a nerve, and herein we have the mystery explained. I do not believe in a nerve force after the general acceptation of the term, as a sort of aura residing in and produced by nerve cells. Let us see how much a reconstructed view will account for the hitherto unaccountable. There are certain natural "forces" or vibrations of matter, called sound, heat, light, electricity, etc. Expose albumen to the influence of any or all of them and determinable motions are produced in its mass. Protoplasm has a definite molecular composition which never fails to be susceptible to these influences. The contractile phenomenon is not a whit more of a mystery than the beautiful laws of electrodynamics as deduced by Ampère from the fundamental experiment of Œrsted: I. *Two currents which are parallel, and in the same direction, attract one another.* II. *Two currents parallel but in contrary directions, repel one another.* To demonstrate this, one current should be fixed and the other movable. In a few words the Amœba is the medium for the movable current while its pabulum is equivalent to the fixed current which attracts the animal. I do not mean to lay this down as actually the case, for the causes of Amœbic movements are multiplex, from which, as might be expected, there would be multiplicity of changes in its sarcode. But this alone would indicate how sufficiently the laws of physical forces may some day go to explain the protoplasmic motions.

We see that all matter is mobile. The molecules of the Amœba are not force proof, and these forces would, from the very homogeneity of the mass, pass in varying directions through the animal as governed by extrinsic causes. But as soon as differentiation began, by even as simple a process as an induration of one part of the protoplasm, currents must be deflected from their former courses. Huxley considers Kleinenberg's fibers of the Hydra as internuncial, and hence the primary form of a nerve. In this case we have a contractile muscle with a nerve differentiated from, and continuous with the muscle. How has this come about?

Immediately upon the definite location of tissue which is more

susceptible to certain external influences, such tissue would quickly differentiate a portion as the path of least resistance, which would also be the most direct conductor of motions from without to the contractile part. Thus the neuro-muscular cells of Hydra appear. From the general mass proceeds the ectoderm, and from it is differentiated the nerve-muscle tissue.

The causes of this differentiation may be conceived by regarding the forms assumed by a layer of the sporules of Lycopodium and sand, when this mixture is subjected to vibrations coarse enough to affect the layer. *The electro-dynamic law which draws together matter transmitting currents in one direction would of itself construct a nerve path to contractile tissue.*

A nerve, then, is internuncial only, and the ganglion cell is histogenetic. Neither have any force-producing power, but are both the media through which certain molecular vibrations are most swiftly transmitted.

The primitive sense is tactile and all senses have proceeded from its differentiation.[1] For illustrative purposes let us consider energy as divided into molecular vibrations, from one ethereal pulsation in an eternity, to an infinite number of vibrations in one second. In such an undulatory series we may see, as a small division of it, all forces from sound to gravitation represented. While the protozoön may be visibly affected by every such undulation, the homogeneity of its composition prevents any differential response; for instance, the tremor of a musical note, heat, light, electricity, alike produce contractions or expansions (motions) of its mass. In a higher form of life nerve tissue appears, which conveys only certain vibrations and rejects all others. Take one undulation in a second as the capacity of this nerve fiber. It is a tactile nerve. When a nerve fiber conveys more rapid undulations differentiation begins. Sixteen to forty thousand per second begin and end the auditory vibrations. Quicker vibrations to four hundred and fifty billion per second we may view as heat appreciation, thence to eight hundred billion from red to violet light, above this fluorescent undulations, " chemical energy," electricity, to infinity. We may thus mathematically conceive an

[1] In a paper read before the American Association for the Advancement of Science, Boston, August 28th, 1880, published in full in the Journal of Nervous and Mental Disease for October, 1880, I treated this subject more with reference to the microscopic anatomy of human nerve systems. Extracts, as above, made from that paper are such portions as refer more directly to our present subject.

auditory sense derived from the general tactile or a special touch sense (like that of the fifth pair of nerves). An optic sense would arise from this same tactile, and we have seen it thus differentiated embryologically.

Qualitative differentiation of the nervous organization proceeds dorsally, with a tendency toward the head end. That portion of the animal which stands in most direct relation to the changing molecular movements of the environment develops the highest sensory and motor nerve-centers and projections.

Repetition of parts of a system, up to a certain point ceases ; and these parts become commissurally united before another system is perfected.

The sympathetic nervous system, consisting of the intestinal and vascular or vaso-motor nerves, develops first. Blending the results of comparative embryology and anatomy, the sympathetic precedes the creation of other systems.

The second system to appear phylogenetically is the spinal, equivalent in the Invertebrates to their "cerebral" ganglia.

The third system is the intervertebral, the swellings upon the posterior roots of the spinal nerves.

The cerebellum is formed from fused hypertrophied intervertebral ganglia.

Many sensory cranial nerves pass through this organ and by the fusion of these originally separate centers coördination occurs necessarily.

Excessive development on the one hand, or want of development on the other, places all the ganglionary tubercles and lobes of the encephalon in the third system category. Thus *the præ-frontal lobe of the cerebrum, the occipital and temporal lobes, the olivary body, the olfactory lobe, the mammillary eminence, the epiphisis cerebri, the tubercula bigemina, the petrosal and Gasserian ganglia were originally intervertebral ganglia,* and still maintain resemblance to these ganglia in many particulars.

The præ-frontal lobe is the last intervertebral ganglion to develop. It grows larger in the scale of intelligence and presses the occipital (see the brains of monotremes and marsupials) backward, downward and forward, thus forming the temporal (or what has been erroneously termed the middle) lobe.

The cerebro-spinal nerves, in some cases, preserve their original projections from and to muscles, but these nerves may also have

not only a distribution to the viscera, as has the pneumogastric, but may also project into and from *other system-centers.* The lateral columns of the spinal cord, the tegmentum and crura cerebri in their main mass may thus be regarded as cerebro-spinal nerves of the highest series, having lower system-centers for peripheries. The præ-frontal lobes thus exert an inhibitory control over the highest centers, because such centers are peripheries for the nerves of these foremost ganglia.

We accept the motions of protoplasm as evidence of life, and yet ungrouped elementary atoms are subject to the play of physical forces, which become known as modes of motion : sound, heat, light, electricity, etc., through the changes in place of atoms and molecules.

Inasmuch as sensations have for their ultimate expression motion in the living organism, cause and effect exchange places in the recognition that forces are manifest to us as sensation only in the molecular movements caused by forces. These molecular movements impress us as sensations which, of necessity, must be translated into some form or forms of motion.

Sensibility and motility, then, are sequentially convertible terms, and we find it none the less true in the most complex than in the simplest forms of life.

There are certain fundamental considerations which should stand in axiomatic relation to all biological inquiries.

1st. Sensibility and motility are merely afferent and efferent terms to express the effects of force upon matter and matter upon force.

2d. In life a primary object of motion is for procurement of food.

3d. Growth depends upon proper nutrition (ingestion).

4th. Multiplication (as fission) proceeds from growth.

5. Food is any material, gaseous, liquid or solid, which tends toward nutrition of the body.

6th. " Development is a process of differentiation by which the primitively similar parts of the living body become more and more unlike one another." (Von Baer.)

7th. " Higher sensory organs are special elaborations with one special function capable of response to stimuli of one special kind. They are developed from the lower kind of sensory organs, and oftentimes still possess the essential structure of that lower kind." (Gegenbaur.)

As illustrative of undifferentiated faculties it may be mentioned that by the Gregarinæ food is taken in by endosmotic processes at the surface. Any place in the protoplasm can act as a digestive cavity by enveloping and absorbing nutritive matter.

It is the simpler view, entertained by some (in opposition to the delamination precedence theory), that the form which preceded the gastrula was a one-layered vesicle which, by invagination, produced the endoderm from the ectoderm. While the ectoderm was undifferentiated, all parts of the cell were assimilative. In the gastrula stage the endoderm acquired specific ingestive faculties. Differentiation of the purely ingestive proceeds thus from the intestine, while the ectoderm remained in contact with the more variable conditions of the environment, and developed the greatest qualitative sensory and motor organs. The entire nervous organization, in its earliest condition, answers to that portion which, in Vertebrata, presides over the vermicular motions of the intestines, and the correlated respiratory and circulatory structures—the sympathetic nervous system. This, therefore, we may entitle the First System. As soon as the enteron is created, by folding in of the ectoderm, qualitative development of this First System is restricted to such functions as are more clearly nutritive, as, when the blood vascular system is differentiated from the mesoderm, the vaso-motor nerves are derived from or added to the sympathetic, and exactly in the ratio of development of the viscera so does the First System differentiation proceed.

In high forms of Invertebrata, but more pronounced in Vertebrata, the viscera, and consequently the First System of nerves, occupy an inferior position, properly termed ventral, while as a broad rule the upper surface of the animal comes most in contact with varying molecular motions of the outer world. Hence, we may say that it comes to be a law, that from the dorsal to the ventral parts of the animal, ingoing impressions proceed, and, of necessity, progressive development must occur, by superimposition upon the ventral system.

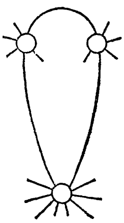
The first appearance of a Second System, equivalent to the spinal cord (segments coalesced) of Vertebrata, is indicated in ganglionic enlargements upon the afferent nerves of the First System.

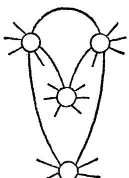
This is apparent in the oyster, whose anterior ganglia (A) are placed upon the fibers leading to the principal ganglion of the

body. (In a typical embryonic, not phylogenetic sense, for the oyster is a degraded Lamellibranch.)

This appears to be a specialization of the tactile sense, with reference to its uses anteriorly in food discrimination and ingestion, involving ciliary prehension and control of the valves. In Pecten further quantitative development of a Second System produces the pedal ganglion (C), also related to the touch sense.

A





C

The cilia of Protozoa subserve ingestive as well as locomotor purposes, and show the relationship of ingestive and general motions, and that the locomotor ability is often derived from the prehensile ingestive. In the free Rotifer this is quite apparent.

As the segments increase the sub-œsophageal ganglia multiply; the first set of ganglia become relatively ventral and preside over nutrition, while the second set, relatively dorsal, indicate progressive differentiation, as control of a pedal extremity or some special organ related externally. At the same time this dorsal ganglion is connected always with the ventral system. Fusion of these segmental ganglia with each other, or with ganglia of other systems, produce confusing appearances. This fusion of systems is most clearly seen in Vertebrata.

The vibrating molecules which produce the undifferentiated impressions upon lower Protozoa may be considered as causing purely tactile excitation. Just as the waves that dash the primitive animal about differ from the ripples that bring it food, only in degree, so the differences between impressions must be regarded. All sensation being related to molecular motions, and all special sense organs being derived from indifferent primaries.

Otocysts in their simplest form are connected directly with nerves, as are the pigment granules which eventually develop into eyes. Prof. Alf. M. Mayer shows that the fibers of the antennæ of the male mosquito vibrate sympathetically to the notes of the female mosquito, and that the vibrations of the insect's antennæ may teach it the direction of sounds (thus allying this sense to

the so-called "space sense" of the human labyrinth). Prof. Mayer also announced that the terminal auditory nerve-fibers vibrate half as often in a given time as the membrane of the tympanum and the ossicles.

In these instances there is a direct derivation of an auditory from the special tactile which, in turn, was evolved from the general tactile sense, and does not seem to be lost, even in man, as a property of sensory nerves.

A heat sense system of nerves developed from pigment terminals, by further elaboration could become ocelli and finally eyes.

A special series of nerves for heat appreciation would have necessarily *a general distribution throughout the body*, to viscera as well as to more external peripheries.

Nervous tissue appears at the same time as muscular, and affords a better path or course of less resistance for the molecular vibrations from without. The muscular is a definitely located expression of what previously belonged to all parts of the animal, contractile ability or motility for assimilative purposes.

This assimilative faculty is essentially prehensile, and in the word prehension we may grasp the idea of a differentiation of such faculties as respiration, locomotion, deglutition, etc.

Carrying the comparison from Protozoa to man, all that man does or may hope to do has for its basis the single fundamental, though widely differentiated faculty of prehension.

Jaws and arms are prehensile, clearly. Ribs are prehensile in the sense that they assist in prehension of oxygen (food) for the lungs, morphologically and less physically in man, while in Ophidia the ribs are locomotory prehensile, direct.

Legs are prehensile directly in quadrumana, and in man in carrying him over ground in search of food.

As mentioned, the next step in development of the nervous system is when the ingoing general impressions become specialized and a secondary ganglion appears upon a sensory strand of the primary, which signifies that from among the general impressions some one sense, as sight, is being specialized. This is outwardly evidenced by formation of ocelli or eyes (leech), which require a special projection.

By quantitative increase multiple eyes may form (leech) and these become united into bilateral organs (pyramidal fusion in crayfish).

The likeness between the chain of ganglia in the leech and the spinal cord of Vertebrata has led many comparative anatomists astray in homologizing. A nearly similar chain of ganglia obtains in Vertebrata but situated ventrally from the vertebral column. This chain is a first system. The head ganglion, only, of the leech, as in most Invertebrata can be compared to a spinal. In Insecta and Myriapoda the superimposed secondary becomes more evident. An " unpaired system " runs in the median line between and connected with the paired or primary system, typifying the more definite appearance of the medullary gray and its commissures below or back of the head.

Todd and Bowman (pages 611 and 614, Vol. III) use the following words, which indicate an early recognition of the anatomical fact without their having seen its connection or full import: " In the bee the cerebral ('secondary') ganglion is very large; from its anterior portion is given off two nerves which pass forward to the base of the antennæ and have their origin well marked by a distinct ganglionic enlargement !"

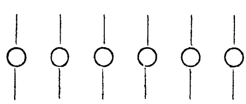
Todd dwells upon the importance of recognizing this distinct ganglionary enlargement, and repeats, " The sensory nerves have ganglionic enlargements in the bee."

(This appearance of a third system is rare in Invertebrata, though the crab and Pterotrachea also may prove to be its possessors.)

The ganglionic swellings which on the sensory nerves of the bee distinguished it from most Invertebrata, in vertebrate types from Cyclostomes upward become more markedly developed.

While both the first and second systems possess recognized afferent and efferent fibers, before being able to comprehend the relationships between systems or the process of projection formation, we must consider whether some fundamental law does not underlie these series of relations which will better account for their creation.

The typical segment is an animal whose nerve center lies midway between an afferent and efferent strand, thus: . A series of such segments, if ununited, present this appearance:



These segments could be correlated by a second fiber, which

instead of passing between peripheries as in the instance of non-union, unite the segmental ganglia by making another ganglion its motor projection.

Carpenter (" Principles of Comparative Physiology," p. 642) expresses this view: " When different organs are so far specialized as to be confined to distinct portions of the system, and each part consequently becomes possessed of a different structure and is appropriated to a separate function, this repetition of parts in the nervous system no longer exists; its individual portions assume special and distinct offices, and they are brought into much closer relationship to one another by means of commissures or connecting fibers, which form a large part of the nervous system of the higher animals. It is evident that between the most simple and the most complex forms of this system there must be a number of intermediate gradations, each of them having a relation with the general form of the body, its structure and economy, and the specialization of its distinct functions. This will be found, on careful examination, to be the case; and yet, with the diversity of its parts as great as exists in the conformation of other organs, its essential character will be found to be the same throughout."

Segmental union, thus, is accomplished through efferent nerves no longer penetrating to primary organs, but passing to nerve centers of other segments, for the purpose of producing coördinated movements, and consequently to exert an inhibitory effect thereupon.

[*To be continued.*]

——:o:——

BOTANIZING ON THE COLORADO DESERT.

BY EDWARD LEE GREENE.

II.

BETWEEN Coyote Wells and the next station lie some twenty-two miles of almost uninterrupted plain. The white clay soil, strong with salts and alkalies, produces no cacti, but there is great abundance of chenopodiaceous shrubs, popularly called grease wood. Yet there is no verdure even here; for although the grease bushes, contrary to the rule of desert growths, are leafy, their abundant foliage is of precisely the same dull whitish color as the clay in which they grow. Over this smooth and slightly yielding clay the walking was very easy, and I made